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ABSTRACT

The ways in which knowledge of mechanical motion is affected by contextual factors of assessment such as means of depiction (ranging from abstract to contextualized) and the effect of sequencing of contexts (from abstract to contextualized or contextualized to abstract) on students' display of knowledge were studied for 40 fifth graders in two inner-city desegregated elementary schools. Students' conceptions of projectile motion were assessed by analyzing their depictions of motion through sketches, their explanations of motion, and one-on-one videotaped interviews. Twenty-three percent of the students could represent predictions of projectile motion accurately through sketches, but could not provide valid explanations of their predictions. Eighteen percent could provide valid explanations but inaccurate sketches of their predictions of projectile motion. As the complexity of the motion increased, contextualized images caused more confusion than did the more abstract images. When the factor order of the contexts is considered, data for projectile motion indicate that when the most contextualized context (videotape) is used, more students sketch accurately. The physical context in which a context is assessed affects what is assessed. More than one-third of the predictions were accurate in sketch or explanation, but not in both. In single context assessment, these predictions could have been misinterpreted. Two tables, 14 graphs, and 43 references are included. (SLD)

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KNOWLEDGE IS NOT ALWAYS WHAT WE TAKE IT TO BE: ISSUES IN THE ASSESSMENT OF STUDENTS' UNDERSTANDINGS OF MOTION

Paper presented at the National Association for Research in Science Teaching (NARST) Annual Meeting
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ABSTRACT

A study was made of the ways in which knowledge of mechanical motion is affected by contextual factors such as means of depiction (ranging from abstract to contextualized) and of the effect of sequencing of contexts (from abstract to contextualized or contextualized to abstract) on students' display of knowledge. The study involved forty fifth grade children in two urban, inner-city desegregated elementary schools. Students' conceptions of projectile motion, as well as circular release and simultaneous horizontal and vertical motion were assessed by analyzing (1) their depictions of motion, (2) their explanations of motion, and (3) one-on-one videotaped interviews. Results indicated that in assessing conceptions of projectile motion, 23% of the students could represent their predictions through accurate sketches, but not provide valid explanations of their predictions. Eighteen percent were able to provide valid explanations but inaccurate sketches of their predictions of projectile motion. As the complexity of the motion increased, the contextualized images caused more confusion than the more abstract images. When the factor of the order of the contexts is considered, the data for projectile motion indicate that when the most contextualized context (videotape) is used more students sketch accurately. This study provides evidence that the

physical context in which a concept is assessed affects what is assessed. The study further implies that display of knowledge is affected by prior experience and knowledge, interests as well as the means of eliciting a student's knowledge. In this study more than a third of the predictions were characterized by accurate sketches or valid explanations but not by both. In single context assessment, these predictions could have been mis-evaluated.

KNOWLEDGE IS NOT ALWAYS WHAT WE TAKE IT TO BE: ISSUES IN THE ASSESSMENT OF STUDENTS' UNDERSTANDINGS OF MOTION

At the present time professional educators as well as the public in the United States are debating the merits of standardized tests and alternative means of assessment. State mandated proficiency and exit tests in math, reading, science and citizenship are flourishing in number as are projects in districts and classrooms that are exploring different ways of assessing knowledge and skills. This study addresses questions raised by those concerned or interested in both movements. These questions include: is the knowledge assessed affected by interaction with the physical context of the assessment?; do student displays of knowledge vary with context?; in using multiple forms of assessment, does the sequencing of the assessment events affect what is assessed?

There is a growing field in classroom research that explores the classroom as a culture and considers knowledge a social construction involving people and materials (Carlsen, in press, 1991; Lemke, 1990; Green, et al., 1988; Cicourel, 1974). Inherent in such a perspective is a concern about the effect of context on peoples' display of knowledge. Much of the earliest work on what is now termed situated knowledge or distributed cognition comes from the field of anthropology (Lave, 1990, 1988; Cole, 1985; Scribner, 1985;

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Geertz, 1983; Knorr-Cetina, 1985). Application of this philosophy of distributed cognition or situational knowledge to learning environments using interactive hypermedia is being actively explored by the Cognition and Technology Group at Vanderbilt University (1990) among others.

Further application of this philosophy to learning environments is found in Kozma (1991). In exploring the effect of the use of media on classroom context, Kozma defined distributed cognition as the relationship between the internal and external cognitive environments and claims learners actively collaborate with media to construct knowledge. This study, Ridgeway (1990), explored an aspect of this relationship in an interview context, more clinical than experimental, with varying conditions.

The framework which guided the design and implementation of the research interviews for this study is described by Mishler (1986). Mishler defined an interview as a joint product of what interviewers and subjects talk about together and how they talk to each other. The record of the interview is a representation of that talk. Notions of constructivism, meaning making in the face-to-face, and the contextual nature of cognition are embodied in Mishler's conception of interviewing. Questions on interviews limit the range of possible responses to a predetermined set of categories that reflect an investigator's prior knowledge

and interests. The qualities of an interview situation, the social and the physical context, determine what is perceived as the students' knowledge. The implication is that what is assessed is one display of student knowledge.

A review of some of the relevant literature follows in order to provide background to the frame of this study. The literature review is organized in sections that highlight research regarding the contextual nature of cognition and the contextual nature of cognition as applied to science education.

LITERATURE REVIEW

Contextual Nature of Cognition

Experience provides many examples that knowledge or cognition is flexible and interactive. Students provided with the same instructional experiences in the same classrooms have historically and repetitively reported and understood varying versions of knowledge of a particular topic, as evidenced by sometimes widely varying formal and informal assessment results (Ridgeway, 1988 and McCloskey et. al., 1981). Knowledge gleaned from observations is sometimes perspective-bound (McCloskey, 1983) and the context in which an event is perceived can directly affect

what is perceived (Kozma, 1991; The Cognition and Technology Group at Vanderbilt University, 1990; McCloskey et. al., 1981).

Knowledge is described as indexing the situation in which it arises and is used according to Brown, Collins and Duguid (1989). In addition to indexing situations, knowledge is coded by and connected to the activity and the environment in which it is developed and is distributed across the component parts, some of which are in the mind and others which are in the world. Bruner (1986) and Bateson (1972) agree with Brown, Collins and Duguid (1989) and both include the notion of multiple perspectives as a dimension of knowing and interaction. In considering the nature of context, Bateson (1979) refers to it as a story through time and claims that nothing has meaning except as seen in some context.

Lave (1988) points out that there is reason to suspect that what we call cognition or knowledge is, in fact, a complex social phenomenon. Empirical support for this proposal has emerged recently from research examining the practice of mathematics in common settings. These studies point towards the view that mathematics is a distributed form of cognition and therefore appears differently in different situations. Lave (1988) explains cognition as a nexus of relations between the mind at work and the world in which it works and

describes her own research exploring mathematical activity as a social anthropology of cognition.

In exploring specific contextual effects on assessment results, Cicourel (1974) points out that we are not clear about how contextual information about sound patterns, their intonation and intensity, knowledge of grammatical rules, visual appearances, and stored information interact with competing sources. These contextual elements may suggest other meanings to the student, or may interfere with the student's performance in classroom or testing situations.

In examining specific studies which provide evidence of the contextual nature of cognition, Stavy (1990) found that children (grades 4 - 10) who recognized weight conservation in a translocation task did not necessarily recognize the same in a melting task, and that those who recognized it in a melting task did not necessarily do so in an evaporation task. The context in which the concept was assessed affected the version of knowledge the students displayed. Stavy reports that until grade seven specific perceptual input from the task dramatically influences students' responses to the conservation of weight tasks. The author goes on to discuss what she feels is a reasonable sequence of instructional activities when the topic is the conservation of weight. Stavy recommends that when a new concept is taught, one should begin with an example that

provides the maximum perceptual reinforcement for accurate and valid intuitive knowledge.

From the field of social studies, McKeown and Beck (1990) focused on the background knowledge that young learners (grades 5 and 6) bring to their study of history by characterizing students' knowledge of events leading to the American Revolution just before and a year after they study the subject in school. The study provided evidence of a lack of flexibility in students' use of concepts. This inflexibility was demonstrated by the great variability in the responses to different questions, despite the fact that the questions represented varying entry points to knowledge of the same basic issues. Students were able to bring relevant concepts to bear in response to some questions, but when questioned from a slightly different perspective they did not access that same information.

The work of McKeown and Beck provides support for the importance of the sequencing of instruction as did Stavy (1990). McKeown and Beck point out that a productive way to handle prior knowledge requirements might be to conceptualize instruction as providing an organizing framework for a topic. The presentation of a framework, either within a text or by the teacher, could facilitate students' abilities to organize both their prior knowledge and incoming information.

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In speculating about whether individuals make connections across contexts, Saxe (1990) argues for a model of cognition in which learning is local to situations, and transfer across contexts is mediated by social processes. In this view, cultural life provides support for transfer of knowledge. Vehicles of this support include systems such as language and numeration, which lead individuals to use knowledge acquired in one context to solve problems in another.

As teachers, such findings prompt questions about the effect of the social and physical context on what students learn, how they learn, and the judgements we make about what they have learned. Saxe (1990) points out that children are engaged in many contexts in which occasions for problem solving emerge. Whether and how they may be able to use or transfer knowledge constructed in one context to address problems in another context is a critical question for both educators as well as students of cognitive development.

Contextual Nature of Cognition as Applied to Science Education

In the field of science education, there is a growing body of knowledge collected in limited ways about students' conceptions of a wide variety of scientific phenomena. Traditional research in conceptions of science uses

terminology that has evolved over t .e. The earliest work describes misconceptions of science or preconceived knowledge (Placek, 1985) and the most recent work refers to conceptions of science (Driver, 1986, 1983) as well as to childrens' science or alternative frameworks of science (Osborne & Freyberg, 1985). Most of this work attempts to describe students' conceptions of science using traditional research techniques and neglects an exploration of the effects of the social and physical context on the meaning that students construct and make available to researchers and teachers.

Table 1 enables a comparison of three representative studies that explore how the context of the assessment affects what is understood about the conceptions of motion held by undergraduates. Other such studies at the elementary level have been sought and not found, indicating a gap in the knowledge base about the nature of student assessment.

The studies in Table 1 explored students' understanding of projectile motion and circular release motion using a line drawing representation (most abstract) of the motion. Understanding projectile motion means understanding that an object takes a curved path when thrown. If a person doesn t understand projectile motion,they may think an object, a baseball for example, goes up at an angle and comes "straight down."

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Coming "straight down" may also be illustrated by predictions people make about what happens when, for example, a yoyo string breaks during the trick known as Around-the-World. Predictions of a "straight down" nature also occur when the motion is that of a ball dropped by a moving person.

When the string breaks in the yoyo trick, the resulting path of the yoyo is tangent to its original circular path. The belief that the resulting path is curved is known as curvilinear impetus. Likewise, the path of the ball dropped by a moving person would be curved forward and a prediction of a backward path indicates the predictor may hold the theory of curvilinear impetus. The notion of impetus was used by Aristotle in describing motion. He and his successors considered it a quantity that a person imparts to an object that causes motion.

Caramazza et al. (1981) found that 11% of the college student subjects, in response to a line drawing, showed evidence of belief in curvilinear impetus. McCloskey (1982) in a study involving responses to a line drawing and an interview found that 42% of his college student subjects held the belief of curvilinear impetus. McCloskey (1983) reported another study, using only line drawings in which 30% showed evidence of curvilinear impetus conception.

Most all of the studies of students' conceptions of mechanical motion involved the straight-down situation whether in circular, projectile or simultaneous horizontal and vertical motion. Pulling from three studies, it is interesting to note that McCloskey (1982) found that 23% of the college students, in response to line drawing (most abstract) of curvilinear motion, showed evidence of what the author called the "straight-down" belief.

Table 2 enables comparison across three studies that explored simultaneous horizontal and vertical motion. The context of elicitation was not constant across the studies - one used videotape (most contextualized), another used line drawing and the third study involved a computer simulation. From the table, McCloskey, Kohl and Washburn (1981) reported that 48% of the college students, responding to a line drawing, held the straight-down belief. In response to a videotape, McCloskey's (1983) study of college students reported that 56% held the straight-down belief.

This particular point is explored further in another study reported by McCloskey, Kohl and Washburn (1981), Table 2. The students responded to a computer simulation of an object moving across a screen in a rectangular box and not in a rectangular box and were asked to draw, on paper, the path of the object relative to the screen and not relative to the box. There were 25 different motions of the ball. When the

box was present, the ball was perceived as moving backward even though it actually moved forward. In trials without the box, the average path was slightly forward; 45% drew straight-down paths (connect this back with the 48%/45% comparison) and 5% drew paths that indicated that the ball would move backward. These results verify the difficulty students have in isolated motion within a moving frame of reference.

In the studies selected for review in Figure 3, there are some interesting comparisons. McCloskey, Kohl and Washburn (1981) explore student knowledge in this context using a line drawing. McCloskey (1983) explores the same context using a videotape and Figure 3 illustrates the variances in response. Both studies involved college students and the illustrate an interesting difference in response to videotaped representation of an object dropped by another object that is moving. Much less accuracy of predicting is noted with the videotape (most contextualized) and a greater number of students, in response to videotape, perceived the object to fall backwards. The more contextualized image causes visual confusion

Fischbein and Stavy (1989) report a study that explored the effects of instruction in mechanics. This study is also the only one that varied the problem context. They used the situation of an object being dropped by another object that

is moving, but varied the problem context by varying the object dropped. Figure 4 illustrates their results for grade 11 students. For grade 12 students, they claim no variance by problem context. The authors attribute the change in student performance to instruction in mechanics. The grade 11 students perceived that the nature of the object determine the path it would take when released.

The literature reviewed here offers wide support for the contextual nature of both knowledge and its assessment. Much of the work explored here considers the effect of the sequencing of instructional activities on the concepts students develop and hold. The body of work in the field of science education related to this study was conducted with college undergraduates and comparison of the occurrence of evidence of curvilinear impetus, the 'straight-down' effect and perceptual confusion (when complex motion is depicted using videotape) across the two age groups raises further questions.

METHOD

Students were asked to make predictions about the flight of a javelin, the path of a yoyo when the string breaks in the trick known as Around-the-World and the path of a ball when dropped by a moving person. For each of the three types of motion, the students responded to three different depictions

of the motion - line drawings, black and white photographs and videotapes with freeze frames.

This study was designed to enable a descriptive analysis of the range of conceptions of science that fifth grade students exhibit in their explanations of projectile motion, circular motion and simultaneous horizontal and vertical motion. A population of fifth grade students, n-40, were the subjects of the study. These students were from two inner city elementary schools in a large desegregated urban school district. Two fifth grade classrooms, each with twenty students, participated in the study. The socio-economic status of the two school populations is similar and the gender and racial statistics for the whole group, n-40 are shown in Figure 1. Within each motion, the effect of the context of elicitation on students' explanations of motion was investigated. To accomplish this, each type of motion was represented using line drawings, black and white photographs and videotapes with motion freeze frames. In order to further investigate the effect of the context of elicitation on students' explanations of motion, the order of presentation of the contexts of elicitation was varied.

One-half of each school group (n-20) were presented with line drawing (most abstract) representations of the motions, followed by the photograph and the videotape (most

contextualized). The remaining students were presented with the videotape representations first, followed by the photograph and the line drawing. For all students the more simple motion, projectile, was presented first, followed by circular release and then simultaneous horizontal and vertical motion.

BACKGROUND

Implementation of the Study

Students were asked to make predictions about the projectile motion of a javelin when thrown, to predict the path of a yoyo whose string broke during the trick known as Around-the-World and to predict the position of a ball relative to a moving person after the ball is dropped. This order of types of motion progresses from simple to complex. In predicting each motion, the students responded to a line drawing (most abstract) , a black and white photograph and a videotape (most contextualized) of each of the three motions.

Line drawings are complete abstractions, with no evidence of natural conditions, i.e. weather, human characteristics, etc. Photographs are less abstract than line drawings but

not as contextualized as videotapes of motion. The continuum is from the decontextualized to the situational.

Data collection involved interviews with stimuli, i.e. the line drawings, photographs and videotapes. The interviews were recorded on audio and videotape. The data from the interviews included predictions which consisted of students' sketches and explanations of motion. The audio recordings of the interviews with stimuli enabled an understanding of students' propositional knowledge at first mention and with probing. Students' sketches illustrated, clarified and extended audio responses and were either accurate or categorized as a kind of inaccurate sketch. The video recordings of the interviews with stimuli provided cues to student understanding such as body language and other non-verbal indicators of thinking and understanding. The video recordings also provided details of the process of sketching and its relationship to the verbal explanations.

The duration of each student interview was approximately 30 minutes. Each interview followed the same general format of presenting information about the sport or game, including history and equipment descriptions, explaining what the student was expected to do, asking the student to explain his or her predictions and then repeating the student's explanation back to them to check understanding.

Materials

With the line drawings, students were presented with stick figures drawn on buff colored poster board. The stick figures were sex-neutral. Buff was chosen as a result of asking a group of fifth grade students their reactions to line drawings and photographs mounted on white, beige, buff and sky blue poster board. The conclusion from their reactions was that the white poster board was a distractor. The conclusion regarding the white background is supported by research in two areas, graphic art theory and human factors research. According to Reilly and Roach (1986), in drawing on the human factors research, overuse of color can prompt the viewer to have a sense of clutter and therefore detract from the task at hand. The same authors also note that warm color backgrounds, such as buff, lend balance to a visual display. From graphic art theory, balance creates feelings of stability and confidence in the viewer.

Reilly and Roach (1986), from the perspective of graphic art theory, also point out that white space around a visual display sets it apart and makes it noticeable. For this study, the sketches and photographs needed to blend with the background and not stand out. The sense of blending and balance was critical to creating a sense of comfort with predicting the paths of the objects depicted in the sketches and photographs.

The line drawings of the javelin and yoyo were mounted on full size poster board. The javelin line drawing was mounted in the lower left part of the board to enable a student to sketch a full parabolic path. To avoid setting parameters for the student's prediction by the position of the drawing on the poster board, the line drawing of the yoyo was mounted in the center of the board so that there would be equal space all around the drawing The line drawing of running and dropping the ball showed a stick figure holding a ball and had another stick figure later in the motion without ball in hand. The second stick figure was positioned at the point it would be when the dropped ball reached the ground. The line drawing of running and dropping the ball was mounted on a quarter of a sheet of poster board because the motion occurred in a smaller area than the javelin. Clear plastic was placed over the poster boards and for the yoyo line drawing the circular path of the yoyo was shown on the plastic with arrows to indicate the direction of motion.

Students were given a non-permanent pen to use to draw the path of motion directly on the plastic. Student sketches were copied onto pre-printed cards. Three cards were used, one for each type of motion. Each card had space for three predictions, line drawing, photograph and videotape. Each type of motion was printed on a different color of card stock.

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The black and white photographs were treated in the same fashion as the line drawings. Females appeared in the photographs of the javelin and running and dropping the ball. The yoyo trick was done by a male. To depict the two positions of the person in running and dropping the ball, an automatic repeat still camera was used and two of those photographs were junxtaposed.

The videotape of the javelin was pulled from a collection of javelin throws from the last women's summer olympics trials. The motion of the thrower was slowed down as she approached the release point and frozen right before she released the javelin. The video of around-the-world with the yoyo shows two people side by side doing Around-the-World and then a slow motion shot of one person doing the trick with a freeze frame.

The video to depict simultaneous horizontal and vertical motion was done with a person running and dropping the ball and consisted of a shot in regular time of running and dropping the ball before the slow motion freeze frame shot in order to help students to be certain about what was being described. Plexiglass was placed in front of the television and students sketched the paths directly on the plexiglass. For the running and dropping of the ball, a person was sketched on the plexiglass to show them the new position of the person.

In exploring the factor of the effect of the order the forty students were each presented with the stimuli in a particular order, either from abstract to contextualized or contextualized to abstract. Unlike the two school groups whose gender and racial demographics were very similar, these groups presented with the two different orders of context of elicitation were similar only in their gender composition. The racial composition of the two groups is vastly different, one containing 35% more African-Americans (Figure 2). The assignment of students to these groups was alphabetical, the first ten in each school that were interviewed were presented with sketches first and the second ten with videotapes first. The above procedures yielded transcriptions and records of student sketches which served as the data

FRAMEWORK FOR THE ANALYSIS

In analyzing the data, the first step was transcribing the audio tapes. Then each videotaped interview was viewed and categories of the types of sketches for each type of motion became evident. The transcripts were carefully checked for accuracy and notes taken on non-verbal interactions during the interviews. The system of note taking used involved four types of notes: the observation notes (descriptions of what is), methodological notes (what was done and why),

theoretical notes (connections, questions,etc), and personal notes (Green, 1981).

Gestures as an example of non-verbal communication, provided cues regarding the students' familiarity with the context of sports and games. Students would often indicate an understanding of a particular motion by simulating the action as in throwing the javelin. They also would, on occasion get out of their chairs and run and drop the pen they were using, trying to make observations of the path of an object under such conditions. This kind of physical motion on their part helped to clarify whether or not they understood my description of the type of motion.

The range of possibilities of students' sketches and explanations were listed. Their explanations were generally rather terse and their sketches either accurate or one type of inaccurate. Before this process began, some systems of propositional analysis were considered. These systems such as Britton & Black (1985), Kintsch & van Dijk (1978) and Miller & Kintsch (1980) were based on text recall, i.e. paragraphs with complete sentences, and were therefore too detailed for my data since the students in this study generally gave terse answers that were rarely longer than a few words. Toulmin's argument pattern as described in Russell (1983) was also under consideration. Although his argument pattern is well-suited to the analysis of arguments

made within specific disciplines, it seems best suited to discourse and therefore did not match the nature of the context of the interview with stimuli used in this study.

Based on the students' explanations at first mention and with probing, their sketches and the non-verbal cues gleaned from video recordings of the interviews, propositions were written that seemed to be evident from these data points. These propositions were of two general types, those that describe the motion and those that explain the motion. Those that describe the motion were often supported by the students' sketches and/or verbal descriptions. Those that explain the motion seemed to be of two types, those attributed to human factors and those attributable to physical conditions.

Factors perceived to affect the motion of an object that were controllable by the person were classified as human factors. Examples include the strength of a person and wind, as in the wind caused by a moving person. Physical conditions are those that are uncontrollable by humans, as in gravity and wind (weather).

For each of the three types of motion, range of possibilities for path descriptions (sketches), human factors and physical conditions was charted. These charts were used to order the data in a variety of ways and they

enabled comparison of data within and across various data groupings. The results of this study, Ridgeway (1990), as they pertain to the effect of context and the effect of the sequencing of contexts on predictions of motion, are presented in the section which follows.

RESULTS

In this study that explored motion from simple to complex in contexts from abstract to contextualized and from contextualized to abstract, forty-four percent of the javelin predictions were characterized by accurate sketches and valid explanations. Each of the forty students provided three predictions in response to each of the three kinds of motion. Figure 5 explores the predictions that were not both accurate and valid for each of the three types of motion. Twenty-three percent of the predictions provided by the fifth graders showed evidence of an ability to represent (sketch) but not explain projectile motion; eighteen percent of the predictions indicated an ability to explain but not represent (sketch) projectile motion.

Five percent of the predictions of yoyo motion following circular release illustrated the ability to represent but not explain; four percent of the predictions were characterized by the ability to explain but not represent.

The fifth grade students in this study generally seemed to lack an understanding of the path of an object following circular release with only 3% of the predictions characterized by accurate sketches and valid explanations.

In predicting the position of a ball dropped by a moving person, 13% of the predictions indicated that the students providing them were able to represent but not explain the motion of the ball; likewise 13% of the predictions showed evidence of an ability to explain but not represent the motion of a ball undergoing simultaneous horizontal and vertical motion. No predictions were accurate and valid.

In exploring how student predictions of projectile motion varied with the context of elicitation, Figure 6 illustrates that more students provided accurate sketches, without valid explanations, in response to the photograph than in response to either line drawing (most abstract) or videotape (most contextualized). Those students who could explain but not represent projectile motion provided fewer valid explanations in response to the videotape representation than in response to either the line drawing (most abstract) or photograph. Using the photograph as the context of elicitation enhanced fifth-grade students' abilities to sketch projectile motion accurately.

When the same categories are used with the student data on circular release motion (Figure 7), the group who were able to represent but not explain the motion provided no accurate sketches in response to the photograph and the numbers providing accurate sketches in response to the line drawing and the videotape were equal at 7.5%. No predictions provided in response to the line drawing were characterized by valid explanations and inaccurate sketches.

Valid explanations with inaccurate sketches were provided by 7.5% in response to the photograph with 5% responding in the same manner to the videotape (most contextualized) representation of circular release motion. Using either the line drawing (most abstract) or the video as the context of elicitation in circular release motion heightened students' ability to represent the motion and using the photograph heightened students' ability to explain.

Figure 8 illustrates the effect of the context of elicitation on students' predictions of simultaneous horizontal and vertical motion. As with circular release, line drawings heightened students ability to represent their predictions using accurate sketches. The photograph as a context also heightened students' abilities to sketch accurately (similar to data for projectile motion). Another similarity between the results of the predictions of projectile and simultaneous horizontal/vertical motion are

the equal numbers of students who can explain or sketch in response to the video context.

In summarizing the effect of context of elicitation on students' abilities to represent and explain projectile, circular release and simultaneous horizontal/vertical motion, the following points are made:

- as a context of elicitation, line drawings heightened the ability to accurately represent or sketch predictions of circular release and simultaneous horizontal/vertical motion. Equal numbers of predictions were characterized by an ability to sketch and not explain, and explain and not sketch, when the line drawing was the context of elicitation for predictions of projectile motion.

- as a context of elicitation, photographs heightened ability to accurately represent or sketch predictions of projectile and simultaneous horizontal/vertical motion. Use of the photograph as the context of elicitation in predictions of circular release motion heightened ability to provide valid explanations.

- as a context of elicitation, videotape (most contextualized) heightened ability to accurately represent or sketch predictions of circular release motion. Equal numbers of predictions were

characterized by an ability to sketch and not explain, and explain and not sketch, when the videotape was the context of elicitation for predictions of projectile motion and simultaneous horizontal and vertical motion.

In exploring the effect on predictions of the sequencing of the images used to elicit those predictions, Figure 9 illustrates the effect of order on students' abilities to represent or explain projectile motion. Figures 10 and 11 break out the information in Figure 9 in order to explore the effect of context on the predictions made by the group presented with the video (most contextualized) context first and on the group presented with the line drawing (most abstract) context first. Figure 12 illustrates the frequency of accurate projectile sketches within the two order groups by context of elicitation.

Figure 9 indicates that presenting the most contextualized image first heightened students' ability to sketch projectile motion. Near equal numbers of predictions in this group were characterized by an ability to sketch and not explain and vice versa. In Figures 10 and 11 the effect of the more contextualized image being presented first is evident from comparing the responses to the video context in the two groups. Twice as many students were able to sketch

and not explain in the group presented with the video image first than in the other group.

More students could sketch and not explain, and explain and not sketch when the photograph context was used following the line drawing (most abstract) context. When the most abstract image was presented first more students were able to provide valid explanations and not accurate sketches. In Figure 12, which explores the frequency of accurate sketches, disregarding explanations, there is evidence that when the most contextualized image is presented first, the accuracy of student sketches is heightened across contexts.

In summarizing the effect of the order of contexts of elicitation on students' abilities to represent and explain projectile motion, the following points are made:

- when the videotape context (most contextualized) was presented first, more predictions were characterized by accurate sketches; across contexts, videotape presented first heightened students' abilities to sketch

- when the line drawing context (most abstract) was presented first, more students provided valid explanations of the motion.

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SUMMARY AND DISCUSSION

This section provides a summary of the results of this study as they pertain to the effect of the context of elicitation on students' predictions of motion. In this study a sketch and an explanation of the motion are considered a prediction. Three types of motion ranging from simple to complex were used. Half of the students (n-20) provided predictions in response to a line drawing of a person throwing a javelin (projectile motion), a line drawing of a yoyo when the string breaks (circular release) and a line drawing of a person running, dropping a ball and running on at the same speed (simultaneous horizontal and vertical motion). This sequence was followed by a sequence with black and white photographs of the same three types of motion in the same order. A third sequence followed using videotape representations of the motion with freeze frames to enable predictions. When this sequence, from abstract to contextualized, was used, more students provided valid explanations of projectile motion.

The other half (n-20) of the group of fifth graders also had three sequences of predictions but they were presented with videotape representation (least abstract) first. Among the predictions of projectile motion in this group there were more accurate sketches across contexts.

When the data are interpreted for the whole group of students, n=40, disregarding the two orders of the contexts of elicitation, the use of the photograph heightened students' abilities to sketch accurately. With circular release motion the photograph had the opposite effect on students' abilities to sketch and heightened students' abilities to provide valid explanations. The results for the whole group of students for projectile and simultaneous horizontal and vertical motion are similar in that the contexts of line drawing and photograph heightened students' abilities to sketch accurately.

This study with fifth grade children is somewhat unique. Almost all the other work was done with college students, some with formal physics instruction and some not (McCloskey, 1983, 1982). McCloskey's work with simultaneous horizontal and vertical motion is similar in some respects (he uses both line drawings and video contexts of elicitation) to this study but some of his results vary widely. For example, McCloskey found that few of the college students he worked with understood projectile motion, whereas the findings of this study indicate that the majority (73%) of the fifth graders understood projectile motion across contexts of elicitation. McCloskey's work with projectile motion and circular release is limited to the line drawing (most abstract) context of elicitation. In a similar example, Caramazza, et al. (1981), reported that

25% of their undergraduate subjects showed evidence, through sketches, that they understood projectile motion.

Figures 13 and 14 show that the group of fifth-graders holds more Newtonian views of simultaneous horizontal and vertical motion (as evidenced by a prediction of forward motion) than did McCloskey's college students. The discrepancies may be due to differences in the line drawings and videotape representations used in the two studies or in the interview context employed in each. These differences may help explain why the phenomenon of being able to sketch but not explain (and vice versa) was observed. This phenomenon, as well as other aspects of the results of this study, have implications for how we assess students, how and what we teach them, and how and what research we pursue in the future.

The ability to explain before being able to represent (sketch) and the ability to represent (sketch) before being able to explain have implications for the content and techniques of assessment. For example, to explore students' understanding of circular release motion, being able to do calculations, is one display of knowledge. This display of knowledge may be at odds with how the student represents (sketches) circular release motion. In considering which context(s) (line drawing, photograph and video) to use in helping students to learn or in assessing what they have

learned, it is important to remember that contextualized is not always better. Evidence that contextualized images are not always the most appropriate is seen in the studies compared in Figures 13 and 14. In both McCloskey (1983) and Ridgeway (1990), almost twice as many students predicted forward motion in response to the more abstract line drawing than in response to the videotape. Visual confusion seems to occur when two or more objects are moving simultaneously. Further support for this observation is found in McCloskey et.al. (1981), Table 2.

Across contexts of elicitation, within each type of motion, sketches and explanations vary particularly as the complexity of the motion increases. The relationship between mode of representation and student response prompts questions about the practice of single context assessment. As teachers, such findings raise questions about the effect of the social and physical context on what students learn, how they learn and the judgements we make about what they have learned.

Considering questions regarding single context assessment brings to mind the theory of learning transfer underlying traditional means of instruction and assessment. According to Perkins and Salomon (1989) a variety of studies from as far back as the turn of the century have failed to uphold the predictions of a theory of learning transfer. In

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general the research on transfer suggests that thinking, when most effective, depends on specific, context-bound skills and units of knowledge that have little application out of context.

The results of this study indicate that more than a third of the predictions of projectile motion were not characterized by both accurate sketches and valid explanations. In this particular case, if students had only been asked to sketch or explain, then different conclusions would have been drawn about many students' understanding of projectile motion. These results highlight concern about traditional testing and the kind of instruction that flows from it.

Lave (1988) concludes that classroom tests put the notion of transfer of knowledge acquired in context-free situations to work, in that they serve as a measure of individual, out-of-context success since the test-taker can only use memory.

Wolf et al (1991) points out that it has taken cognitive research from Soviet and Asian cultures to suggest that a critical determinant of cognitive growth may reside in the individual's ability to imitate, eavesdrop, borrow or seek help. He traces traditional means of assessment back to an implicit epistemology characterized by the notion that individuals arrive and die in this world with fixed amounts

of intelligence. According to Wolf, the only hope for public schooling is to organize and be informed by those realities and to develop tracks and instructional sequences in which the acquisition of conventions and basic skills acts as a gatekeeping mechanism. And the only reasonable way to make the system rational is for each student to take the same scientifically designed tests and to be educated according to the results.

This notion that assessment drives instruction is not a new one. There is mounting evidence of another notion - that classroom interactions drive what is considered as knowledge. Both Wolf (1991) and von Kugelgen (1990) discuss research that indicates that students who do well on tests and are assessed by their teachers as understanding certain concepts may, in fact, be unable to apply those concepts in the context of use.

For years, research has indicated that the theory that learning transfers out of context, does not match what is observed in students' behavior. The argument was that the more contextualized learning experiences a student has, the more likely the learnings will transfer. The results of this study and others challenge this general belief and point out that the illusion created when students responded to videotapes of certain kinds of motion does not enable them to take a variety of perspectives in solving the

problem. As always, careful thought and experience should precede decisions to use a contextualized image of motion. Perhaps enhanced videotapes that highlight particular features of motion and/or interactive video programs can reduce the perceptual confusion.

Since assessment and instruction are so inextricably linked, the implications of the results of this study for instruction are similar to those for assessment of that instruction. The ways students learn well should determine the ways in which we teach; the ways in which we teach should guide and inform how we assess student learning; and the ways in which teachers learn well professionally about students' learning, should determine the ways in which the growth of their own art and knowledge are given professional support (Hawkins, 1990).

Ellsworth (1990) sums up the effect of the way we choose to organize learning

> Educators construct for students representations of the world in language and image. Everytime we organize narrative in our classrooms we are implicated in the organization of a particular way of understanding the world and the concomitant vision of one's place in that world and in the future (p. 11).

The discrepancies in the findings of this study and McCloskey (1983), as shown in Figures 13 and 14, require explanation through further work. This figure shows that this group of fifth graders hold more Newtonian views of simultaneous horizontal and vertical motion than did McCloskey's college students. The research reports provide very little information regarding these issues. Replication of these studies with various age groups could provide valuable insights.

Future work needs to be undertaken that explores the effect of contextual factors on students' display of knowledge in actual classroom settings. Lemke (1990) indicates that contextual factors of a communicative nature directly impact the ways that students display their understanding of scientific concepts. Likewise, the work of The Cognition and Technology Group at Vanderbilt University (1990), indicates how the physical as well as social context of learning experiences impact what students come to understand and how they display what is understood. In addition, research about common instructional practices and their effect on what is displayed and how it is interpreted is needed to enable construction of a picture of where the field of science education is and where it needs to be directed.

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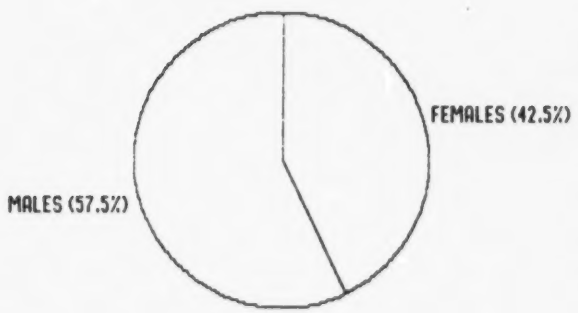
TABLE 1 REPRESENTATIVE STUDIES

	RIDGEWAY (1990)	MCCLOSKEY (1982)	MCCLOSKEY (1983)
#	40	13	18
AGE	FIFTH GRADERS	UNDERGRADUATES	UNDERGRADUATES
TASK	SKETCHED A PREDICTION	SKETCHED A PREDICTION	SKETCHED A PREDICTION
CONTEXT OF LINE DRAWINGS ELICITATION	LINE DRAWINGS	LINE DRAWINGS	LINE DRAWINGS
UNDERSTAND PROJECTILE MOTION	43%	18%	X
HOLD STRAIGHT-DOWN BELIEF	20%	23%	32%
UNDERSTAND CIRCULAR RELEASE	3%	X	51%
HOLD CURVI-LINEAR IMPETUS BELIEF	97%	42%	30%

TABLE 2 REPRESENTATIVE STUDIES

	MCCLOSKEY ET.AL. (1981)	MCCLOSKEY ET. AL. (1981)	MCCLOSKEY (1983)
#	80	18	18
AGE	UNDERGRADUATES	UNDERGRADUATES	UNDERGRADUATES
TASK	SKETCHED A PREDICTION	SKETCHED A PREDICTION	SKETCHED A PREDICTION
CONTEXT OF ELICITATION	LINE DRAWING	COMPUTER SIM-ULATION	VIDEOTAPE
UNDERSTAND SIMUL. HORI/VERT	45%	X	22%
HOLD STRAIGHT-DOWN BELIEF	48%	45%	56%
HOLD BACKWARD MOTION BELIEF	7%	5%	22%

FIGURE 1
GENDER/RACIAL STATISTICS, N=40



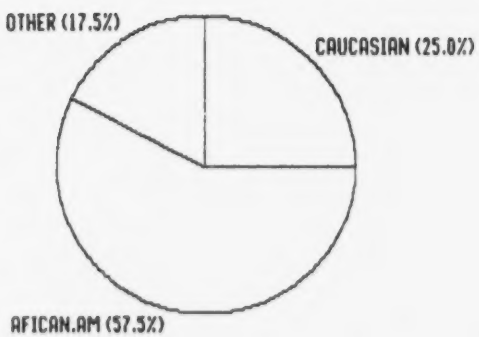
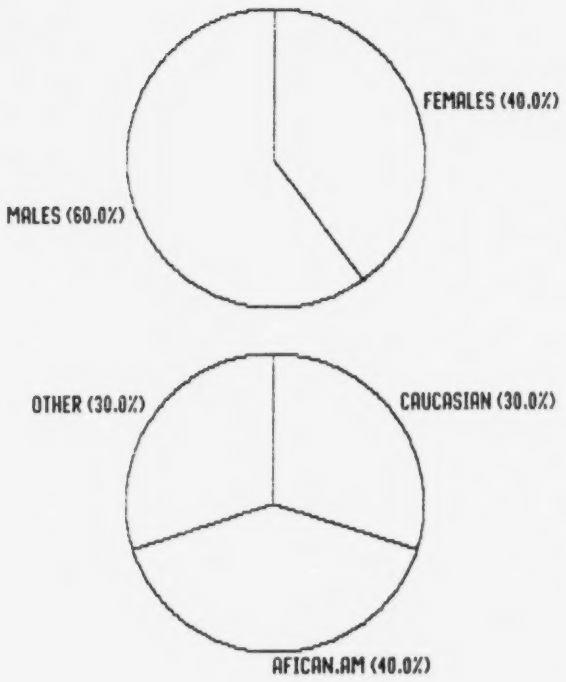
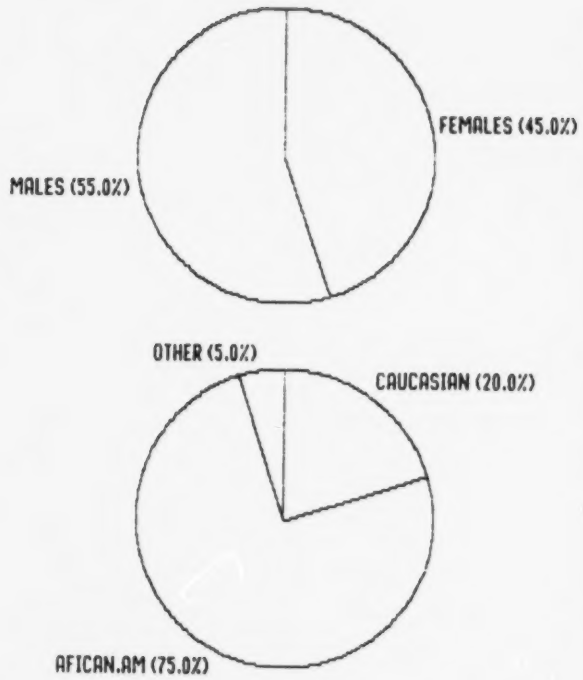


FIGURE 2
GENDER/RACIAL STATISTICS



DRAW 1ST, N=20



VIDEO 1ST, N=20

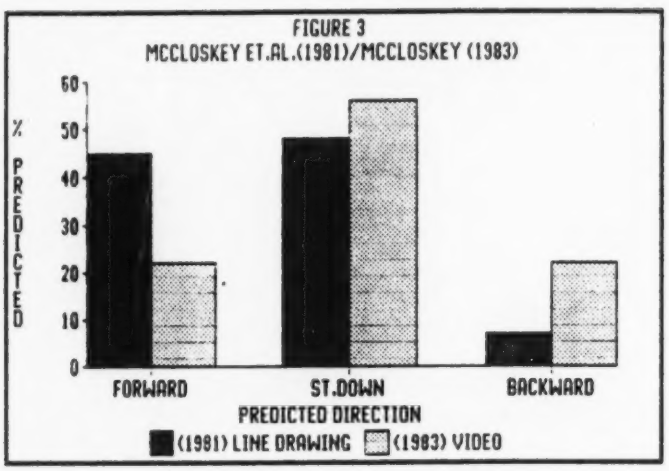


FIGURE 3
MCCLOSKEY ET.AL.(1981)/MCCLOSKEY (1983)
60
50
40
30
20
10
0
%
PREDICTED
FORWARD
ST.DOWN
BACKWARD
PREDICTED DIRECTION
(1981) LINE DRAWING
(1983) VIDEO

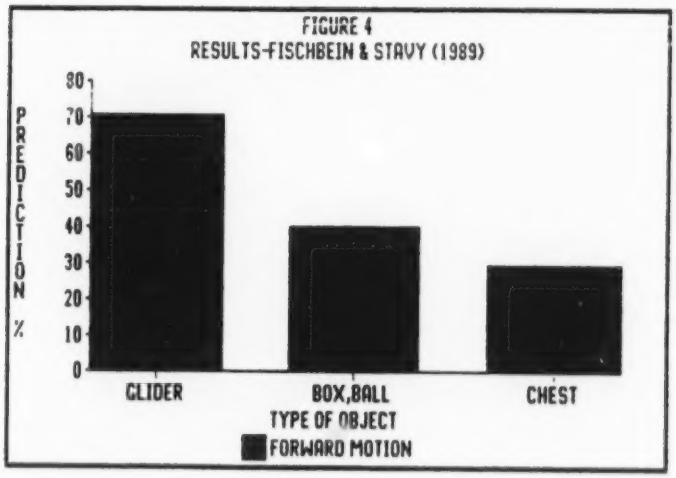
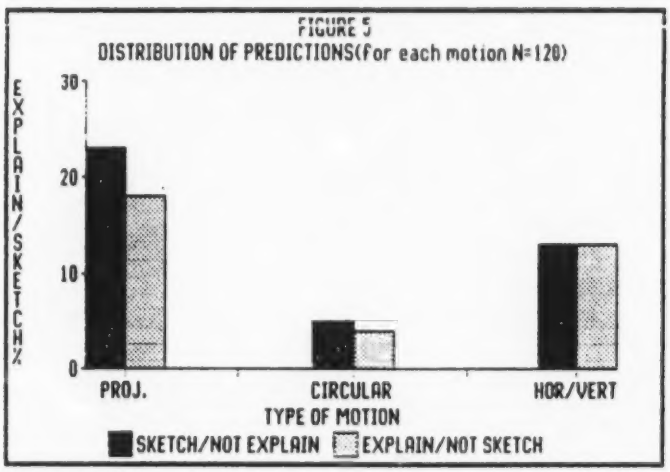


FIGURE 4
RESULTS-FISCHBEIN & STAVY (1989)
PREDICTION %
80
70
60
50
40
30
20
10
0
GLIDER
BOX,BALL
CHEST
TYPE OF OBJECT
FORWARD MOTION

FIGURE 5


DISTRIBUTION OF PREDICTIONS(For each motion N=120)
EXPLAIN/SKETCH%
30
20
10
0
PROJ.
CIRCULAR
HOR/VERT
TYPE OF MOTION
SKETCH/NOT EXPLAIN
EXPLAIN/NOT SKETCH

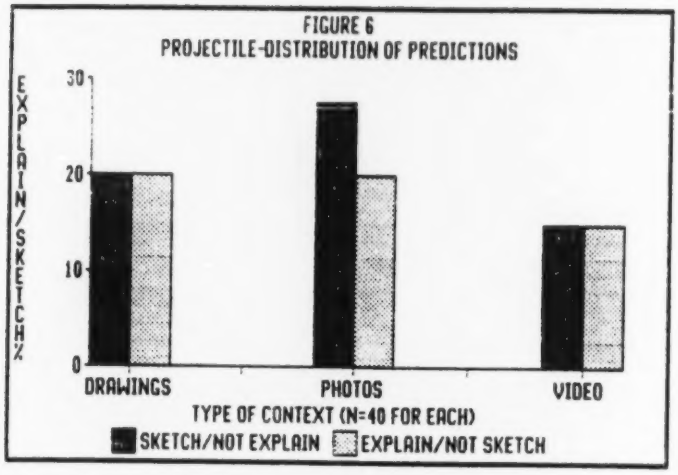


FIGURE 6
PROJECTILE-DISTRIBUTION OF PREDICTIONS
EXPLAIN/SKETCHX
30
20
10
0
DRAWINGS
PHOTOS
VIDEO
TYPE OF CONTEXT (N=40 FOR EACH)
SKETCH/NOT EXPLAIN
EXPLAIN/NOT SKETCH

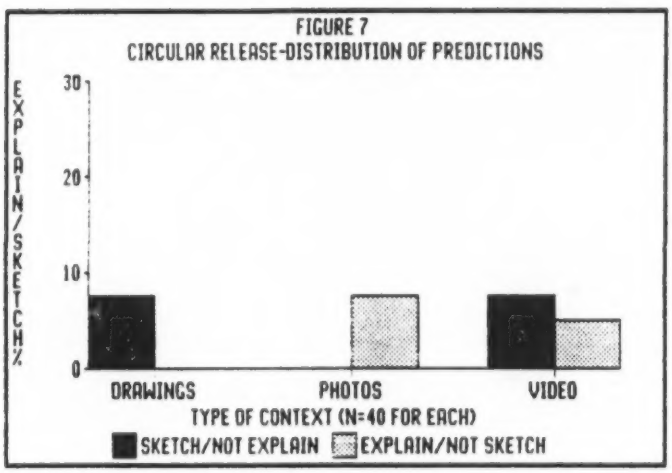


FIGURE 7
CIRCULAR RELEASE-DISTRIBUTION OF PREDICTIONS
EXPLAIN/SKETCH%
30
20
10
0
DRAWINGS
PHOTOS
VIDEO
TYPE OF CONTEXT (N=40 FOR EACH)
SKETCH/NOT EXPLAIN
EXPLAIN/NOT SKETCH

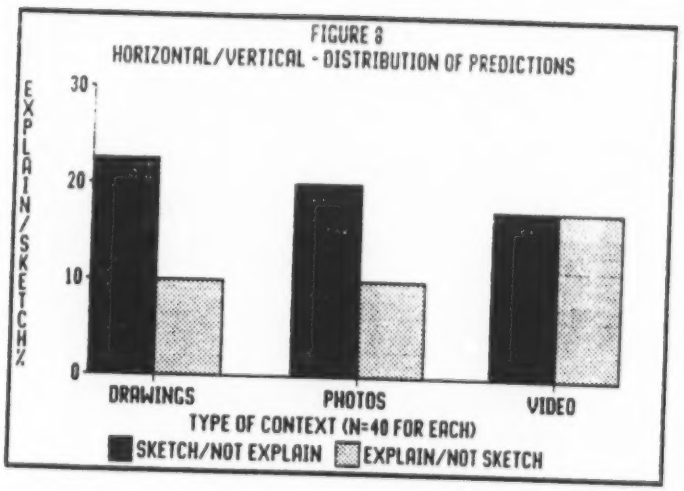


FIGURE 8
HORIZONTAL/VERTICAL - DISTRIBUTION OF PREDICTIONS
EXPLAIN/SKETCH%
30
20
10
0
DRAWINGS
PHOTOS
VIDEO
TYPE OF CONTEXT (N=40 FOR EACH)
SKETCH/NOT EXPLAIN
EXPLAIN/NOT SKETCH

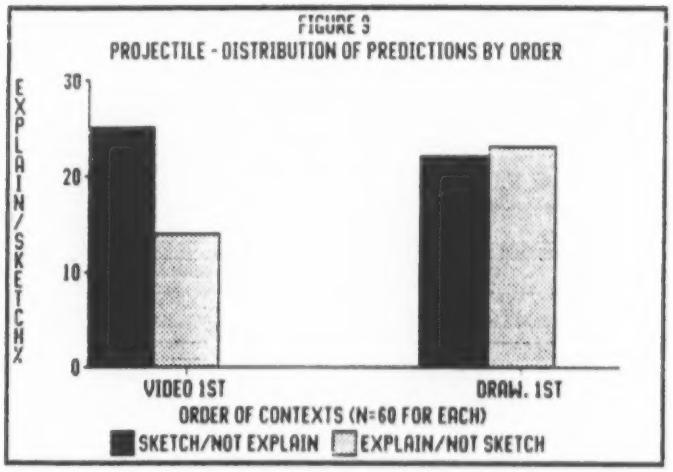


FIGURE 3
PROJECTILE - DISTRIBUTION OF PREDICTIONS BY ORDER
EXPLAIN/SKETCHX
30
20
10
0
VIDEO 1ST
DRAW. 1ST
ORDER OF CONTEXTS (N=60 FOR EACH)
SKETCH/NOT EXPLAIN
EXPLAIN/NOT SKETCH

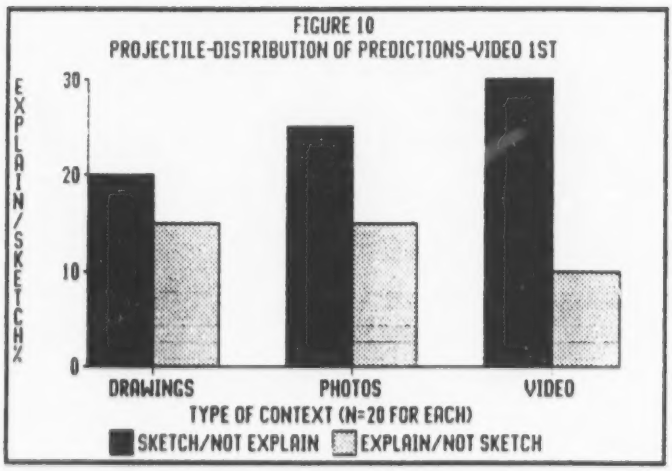


FIGURE 10
PROJECTILE-DISTRIBUTION OF PREDICTIONS-VIDEO 1ST
EXPLAIN/SKETCHX
30
20
10
0
DRAWINGS
PHOTOS
VIDEO
TYPE OF CONTEXT (N=20 FOR EACH)
SKETCH/NOT EXPLAIN
EXPLAIN/NOT SKETCH

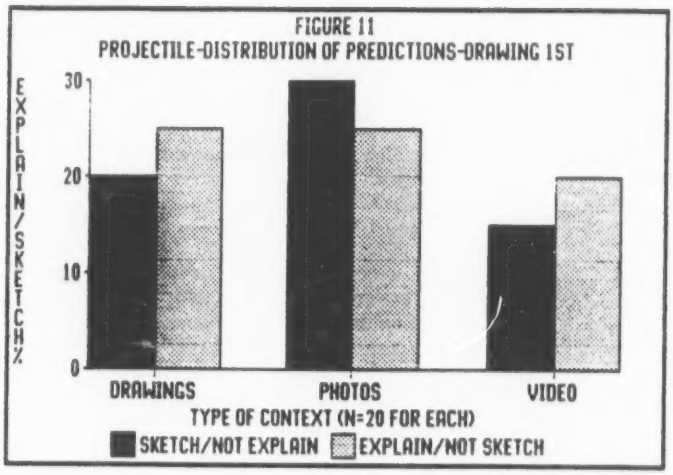


FIGURE 11
PROJECTILE-DISTRIBUTION OF PREDICTIONS-DRAWING 1ST
EXPLAIN/SKETCH%
30
20
10
0
DRAWINGS
PHOTOS
VIDEO
TYPE OF CONTEXT (N=20 FOR EACH)
SKETCH/NOT EXPLAIN
EXPLAIN/NOT SKETCH

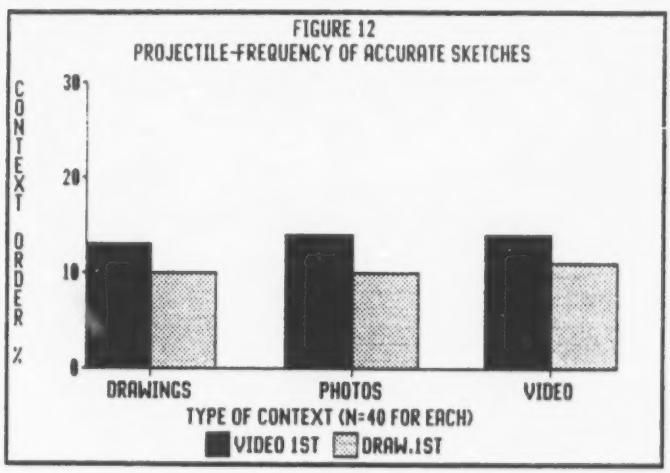


FIGURE 12
PROJECTILE-FREQUENCY OF ACCURATE SKETCHES
CONTEXT ORDER %
30
20
10
0
DRAWINGS
PHOTOS
VIDEO
TYPE OF CONTEXT (N=40 FOR EACH)
VIDEO 1ST
DRAW.1ST

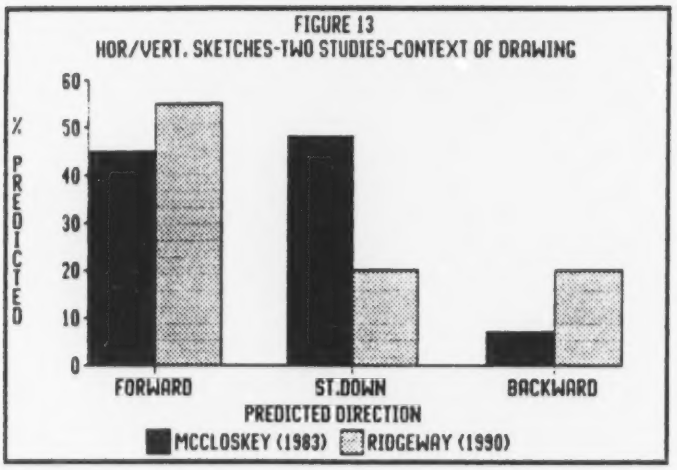


FIGURE 13
HOR/VERT. SKETCHES-TWO STUDIES-CONTEXT OF DRAWING
% PREDICTED
60
50
40
30
20
10
0
FORWARD
ST.DOWN
BACKWARD
PREDICTED DIRECTION
MCCLOSKEY (1983)
RIDGEWAY (1990)

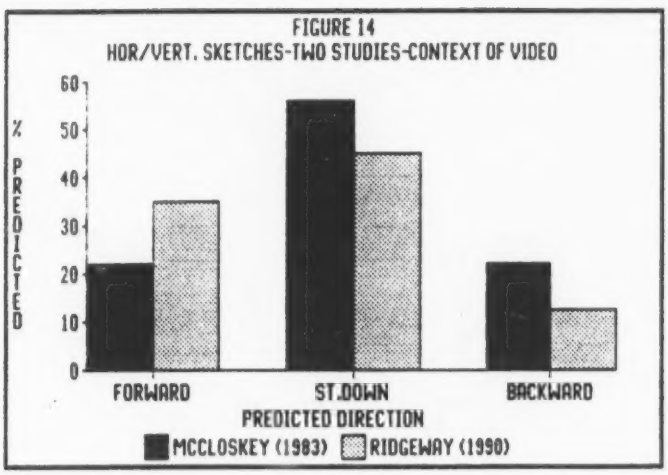


FIGURE 14
HOR/VERT. SKETCHES-TWO STUDIES-CONTEXT OF VIDEO
% PREDICTED
60
50
40
30
20
10
0
FORWARD
ST.DOWN
BACKWARD
PREDICTED DIRECTION
MCCLOSKEY (1983)
RIDGEWAY (1990)